IMPROVED BLIND FASTENER AND METHOD OF SETTING

The present invention relates to blind fasteners of the type that can be inserted through a workpiece and secured therein by a setting operation carried out from one side of such workpiece. More particularly, this invention is directed to a blind fastener utilising a pull mandrel to effect the setting operation by compressing and deforming the tubular body of the fastener to compress such workpiece between the deformed part of the body and a radially extending flange and an improved method of setting such fastener and connecting workpieces thereby. Wherein numerous variants of the blind fastener are known, the most commonly available will be in the blind rivet, as example of which is such as that sold by the Applicant under their registered trade mark POP®.

Conventional blind rivets are used in areas where access to both sides of an appropriate workpiece to be secured is difficult or not possible. The conventional blind rivet is then inserted through pre-formed holes in the workpiece or workpieces whereby the rivet body is subsequently compressed by a compressive force applied to the mandrel of such rivet causing the rivet body to expand within the hole and to also form a compressed joint on the blind side of the workpiece which compresses the workpiece between such deformed body and the mandrel head. Since the rivet body is compressed by the mandrel, the rivet body expands within the hole and a robust joint is achieved and the workpiece parts are pulled into intimate contact with each other. Conventional blind rivets require previously prepared holes in the workpiece materials. This results in frequent instances in which these holes are larger than those specified for good blind rivet practice, which can be caused due to difficulties in hole alignment and/or as a result of the cumulation of hole tolerances. This is particularly common with large workpieces of relatively thin material, such as employed in automotive bodies. In addition, conventional blind rivets can have difficulty in achieving the necessary hole filling and clamping performance in larger holes and there is also an attendent difficulty in insertion of the rivet through the workpiece material due to the holes over-lapping one another. If the rivets cannot achieve good hole filling and clamping, especially where the joint is subjected to vibration or deflection, the workpiece parts can begin to move relative to one another resulting in squeaks and rattles or even to distortion of the holes.

One attempt to address such problem has been the development of a self-drilling blind rivet such as that disclosed in an earlier British patent held by the Applicant, GB Patent No 1484259. Here, the blind rivet is provided with an appropriate drill-point

incorporated into the mandrel head which is rapidly rotated and brought into contact with the workpieces to effect a drilling operation to cut through the workpiece. Once a hole has been drilled using this self-drilling blind rivet it can then be pushed through such hole and set in a conventional manner. However, a major draw back of such self drilling blind rivets is that they are expensive to manufacture, requiring a specialised cutting edge formed onto the mandrel head and further require the use of expensive application tools. Additional disadvantages of such self-drilling blind rivets is that during the drilling operations small chips from the drilling is generated which, if produced in a sealed container or difficult to access area, may result in debris remaining in the finished article.

Secondly, after setting of the self-drilling blind rivets, the protruding drill point remains on the retained mandrel head, creating a sharp and potentially dangerous projection which could, in many instances, present a hazard.

As a further alternative to using blind rivets for holding workpieces together which require preformed holes, there has been developed self-piercing rivets which are characterised by their semi tubular form and which may be used to secure two workpieces together in the absence of any pre-prepared holes. These self-piercing rivets necessitate access to both sides of the workpiece whereby it is then possible to arrange for a single rivet to be forced through a first workpiece and into, but not through, the second workpiece material and to be expanded therein to secure together the two workpieces. Such operation however does necessitate that the workpiece materials are securely clamped together prior to the setting operation (thereby necessitating access to both sides of the workpiece) whilst it is also very difficult to determine whether or not a good joint has been created since there is no visible means of detecting whether sufficient deformation of the self-piercing has occurred within the lower workpiece material thickness. Also, where a workpiece thickness is thin, and normally below 1mm, or a combined thickness of less than 2mm, self-piercing rivets have difficulty in achieving a satisfactory joint without piercing through these materials. The self-piercing rivets are also not applicable if non-metallic, and particularly plastic materials, are used.

It is therefore an object of the present invention to provide a method of securing together two or more workpieces by use of a blind fastener without the need of preformed holes and in a manner which alleviates the aforementioned problems within the art. A further object is to provide a blind fastener for use in such a novel method.

According to the present invention there is now provided a method of connecting together at least two workpieces using a blind rivet which comprises the steps of firstly positioning the at least two workpieces in abutment, positioning a blind side end face of a blind rivet against a first one of said workpieces and applying a biasing force thereto to maintain the rivet in engagement with the workpiece, rotating the rivet at a speed whilst maintaining the biasing force thereon, thus utilising the biasing force to drive the rotating blind rivet through the resultant heat weakened workpieces, stopping rotation of the inserted rivet and setting the blind rivet to compress the workpieces between a deformed portion of the rivet body and a flange portion thereof. The frictional resistance to rotation of the rivet body abutting the workpiece when held in abutment thereof generates a local heat around the area of contact serving to weaken the workpiece and allowing the biasing force to be sufficient to force the blind rivet through such weakened material, thereby minimising the force necessary to force the rivet through a workpiece and reducing and alleviating the possibility of deformation of the workpiece in the area of insertion of the rivet.

Preferably, the rivet is rotated at a speed of at least 200rpm.

Preferably, the biasing force is predetermined so as to be less than that required to force the blind rivet through the non weakened workpiece and will usually be between 2*kN* and 10*kN* (kilo Newton) and preferably this biasing force is between 4*kN* and 8*kN* for low carbon steel workpieces. For aluminium, this biasing force may be between 2*kN* and 6*kN*.

These forces are insufficient to effect normal displacement of a blind rivet through conventional workpieces.

Preferably, the speed of rotation of the rivet in abutment with the workpiece will be between 300rpm and 1,000rpm.

To increase the frictional resistance between the rotating rivet and the workpiece, the method may employ use of a blind rivet wherein the blind side end face comprises an abrasive surface, which may serve to increase frictional engagement and heat generation by such relative rotation.

Preferably, the method will employ the use of a blind rivet having a blind side end face with a workpiece engaging portion having a contact area less than the cross sectional area of the rivet thereby increasing the pressure exerted by the rivet on the workpiece via the blasing force. Such a blind rivet will usually be provided with a tapered or frusto-conical blind side end face.

It is preferred that the step of rotating and subsequently setting the blind rivet can be carried out using the same tool, a specialised rotational blind rivet setting tool. This allows a one step insertion and setting operation significantly reducing the time and hence associated costs in connecting together two workpieces as compared to the previous method of firstly pre-drilling a hole then inserting and setting the blind rivet.

Further, according to the present invention there is also provided a blind rivet for use in the aforementioned method having a parabolically curved blind side end face disposed co-axially with a longitudinal axis of the rivet. Alternatively, there is also provided a blind rivet for use in the aforementioned method having a frusto-conical blind side end face disposed co-axially with the longitudinal axis of the rivet, preferably having an elongate cylindrical projection extending co-axially from such frusto-conical end face.

Either of these blind rivets may comprise either an open ended rivet body wherein the blind side end face is formed on a mandrel head extending beyond such rivet body, or alternatively may comprise a closed end blind rivet wherein the blind side end face is formed on the closed end of the rivet body. In either case, the blind side end face may be formed with an abrasive surface so as to enhance frictional resistance when rotated against a workpiece. This abrasive surface would preferably comprise a coating of abrasive material.

Still further according to the present invention there is a provided a blind rivet comprising a workpiece engaging blind side end face wherein such end face is provided with an abrasive surface.

A preferred embodiment of the present invention will now be described, by way of example only, with reference to the following illustrative drawings in which:-

Figure 1 is a side elevation schematically illustrating the rotation and insertion of a blind rivet according to the present invention; and

Figure 2 is a side view of the blind rivet of Figure 1 in a set configuration; and

Figure 3 is a side view of three variant designs of blind rivet for insertion using the method shown and described with reference to in Figure 1; and

Figure 4 is a side elevation of a blind rivet setting tool utilising the method of the present invention.

The present invention is directed to a specific and novel means of inserting blind fasteners, and particularly blind rivets, into workpiece materials without pre-prepared holes. In its simplest form, this is achieved by utilising the rivets to generate its own hole by rotating the rivet and simultaneously applying pressure to the rivet against the workpiece. Rotation of the rivet results in the generation of heat by virtue of work done overcoming the friction between the rivet and the surface of the workpiece, whereby the heat will soften or reduce the strength of the workpiece material locally to the area of contact such that the rivet can then be inserted under a much lower load through the weakened workpiece. This can be achieved by using an attachment to a static multi-head rivet setting machine or by a special purpose hand-held tool that combines both a means of rotating the rivet and also a means of subsequently setting such blind rivet.

Referring now to Figure 1, the basic operation and principle of the present invention is now shown. A conventional blind rivet (10) is shown comprising a substantially cylindrical tubular body (12) disposed concentrically about a rivet axis (A) and having a uniform external diameter. A front end of such rivet body is provided with a radially extending flange portion (14) having a greater external diameter than that of the body (12). This flange portion forms a radial shoulder portion (16) extending substantially perpendicular to the rivet axis (A). A rivet mandrel (18) comprises a cylindrical mandrel stem (20) which passes through the cylindrical body (12) so as to be substantially coaxial about the rivet axis (A) and which is usually received in a close frictional fit within the internal diameter of the rivet body. A remote end of the mandrel (18) is provided with a mandrel head (22) having a greater diameter than the mandrel stem and which mandrel head diameter is substantially equal to or slightly greater than the external diameter of the rivet body (10). A shoulder portion is formed between the mandrel head and the mandrel stem (20) which then sits and abuts with the longitudinally facing tail end portion (24) of the rivet body (12) remote from the mandrel head (14). This is a standard blind rivet configuration and is readily understood by those

skilled in the art and need not be described in any great detail herein. The mandrel stem (18) is further provided with a weakened or narrow neck portion by which the mandrel stem can be broken during the setting operation at a predetermined position under a predetermined load. The setting operation will briefly be described below.

Blind rivets (10) of this type are used for connecting together two or more workpieces whereby access to a remote or blind side of such workpiece is often difficult or not permitted. An example of such an inaccessible workpiece would be the connection of a first workpiece in the form of a rung or tread of a ladder to an aluminium box section as part of a domestic step ladder assembly. The box section does not permit access to its interior surface and thus any fastener can only be secured from external engagement. This is schematically illustrated in Figure 1 whereby the ladder tread is shown schematically as workpiece (30) and thus box section is shown in part section by reference numeral (32).

Once the first workpiece (30) has been positioned and correctly aligned relative to the second inaccessible workpiece (32) the blind side of the rivet (10), notably in this embodiment, the mandrel head (22), is moved into engagement with the first workpiece (30) and an appropriate engagement force is applied thereto and illustrated schematically by arrow (40) so as to force the rivet head (22) into engagement with the workpiece (30). The engagement force applied to the rivet which effectively serves as a biasing force to maintain the rivet in engagement with the workpiece, is predetermined so as to be sufficient to allow the rivet to be subsequently forced through the workpiece when weakened as will be described below, but is insufficient to effect displacement of the blind rivet through the workpiece in an unweakened condition. It is also preferred that the biasing force is pre-selected such that unwarranted deformation of the workpiece in the region of the blind rivet is avoided. For this reason, it is preferred that the biasing force will be between 2*kN* and 10*kN*. Preferably this biasing force is between 4*kN* and 8*kN* and will, of course, vary for different workpiece materials. For examples, for aluminium workpieces the biasing force may be in the range of 2*kN* and 6*kN* whereby for plastic material such biasing forces may reside in the range of 2*kN* and 4*kN*. Obviously, different materials and grades of materials and thickness will dictate the choice of rotational speed and biasing force.

In the embodiment shown in Figure 1 the mandrel head (22) has been modified so as to be suitable for appropriate blind spin riveting. Effectively, a contact projection (42)

having a smaller cross sectional end face than the cross sectional area of the entire mandrel head is provided. Obviously, the smaller the cross sectional area of contact between the blind rivet and the workpiece will increase the pressure being applied by the rivet (10) on that workpiece. In this embodiment a remote end projection (42) is provided having a cross sectional area of between 10% and 50% of the overall cross sectional area of the mandrel head.

Once the mandrel head has been bought into frictional engagement with the workpiece it is then caused to rotate at a speed of at least 200rpm revolutions per minute (illustrated by arrow 41 in Figure 1). The actual speed of rotation is dependent on the materials being used in both the rivet and the workpiece and may be anywhere between the range of 300rpm and 1000rpm and preferably between the range of 400rpm and 800rpm. The higher the speed of rotation then the greater the heat generation due to the frictional resistance between the mandrel head of the rivet and the workpiece. More surprising to the applicant is that whilst high speed rotation is effective in generating sufficient heat so as to provide appropriate weakening of the workpieces, similar satisfactory weakening of the workpiece can be achieved at much lower rotational speeds of as low as 200rpm.

The resultant heat generated by rotation of the rivet will serve to soften or reduce the strength of the workpiece material (30) in an area locally to engagement with the rivet such that the rivet can then be inserted through this weakened material under a much lower insertion force than normally required to punch through the workpieces. Due to the close proximity and engagement between the workpiece (30) and the workpiece (32) such heat transfer is propagated by conduction between the two workpieces serving to weaken both the outer workpiece (30) and the inner workpiece (32) allowing the rivet to be forced through this weakened material in a self-piercing operation. This piercing operation is enhanced by the high pressure exerted by the small area of contact between the rivet body and the workpieces.

Once the mandrel head (22) has pierced both workpieces (30, 32) the insertion force (40) serves to continue moving the blind rivet (10) through the newly formed hole in these workpieces until the shoulder (16) of the flange portion (14) abuts with the outer workpiece (30) as shown in Figure 2. In this position the rivet can be set in a conventional blind rivet setting operation by firstly discontinuing rotation of the rivet body (12) and then applying a setting force (46) (as shown in Figure 1) to the mandrel stem

(20) whilst utilising an appropriate setting tool to maintain the flange portion (14) in engagement with the workpiece (30). This setting force then exerts a compressive force, through the mandrel head (22), onto the tail end portion of the rivet body until such time as the rivet body (12) collapses under such compressive force in a conventional manner forming a deformed portion (50) of the rivet body on the blind side of the workpieces (30, 32) serving to compress the workpieces (30) and (32) between such deformed portion (50) and the flange portion (14) as is conventional for blind rivets of this type. Continued application of a setting force (46) will cause an increase in stress on the mandrel stem (20) since no further displacement of the mandrel head will be permissible due to the resistance incurred by the rear part of the workpieces (32), until such time that the mandrel stem breaks at a predetermined break neck portion (not shown) as is conventional. Once the rivet (10) has been set in this standard manner, the mandrel head may be ejected from the rivet body (12) or retained therein, dependent on the specific nature and design of the blind rivet employed. Both options are again conventional within the art of blind rivets and are considered incorporated within this broad inventive concept.

A particular advantage of the method of setting blind rivets in this manner is that the insertion force (40) that needs to be applied to the rivet so as to force it through the workpieces (30) and (32) is considerably reduced in comparison to that that would be associated if no weakening of the workpieces had been achieved by heating resultant from such rivet rotation. This significantly reduces and alleviates deformation of the workpieces in the region of the set rivet which is highly undesirable in those fields where such blind rivets are used, particularly within the automotive industry.

In addition, the preferred invention it is preferable to use an appropriate setting tool which is capable of both rotating the blind rivet and undertaking the conventional blind rivet setting operation once inserted through the workpiece. However, the current invention is equally applicable to utilisation of a dedicated rotary tool to first permit rotation and insertion of the blind rivet into the workpiece following which a second and distinct blind rivet setting tool can then be employed to undertake the setting operation.

It has further been determined that specific designs of blind rivets prove advantageous in use in this spin rivet setting operation. Referring to Figure 3, there are shown three blind rivet variants (70, 80, 90) whose specific design configurations exhibit specific spin rivet setting characteristics, each of which are beneficial to specific

operations. In particular, the workpiece engaging end faces of the rivets (70, 80, 90), which in this embodiment comprises the mandrel heads (22), are provided with a unique profile each of which have specific beneficial functions when used in spin riveting. The mandrel head (22) of rivet (70) is provided with a generally parabolically curved end face and, in this specific embodiment, a hyperbolically curve cross sectional profile. This provides for a very small initial area of contact between the rivet head and the workpiece during the initial rotatable engagement therebetween whereby the shape generated by such hyperbolic curve will give initially a focus to generating heat at its point of contact, followed by a rapid insertion as the relative softened workpiece material passes over the curved surface in a manner similar to the way an armaments bullet passes through material. This piercing action is enhanced by the extremely high pressure exerted from a minimal force applied to the rivet during insertion resultant from the small area of contact between the workpiece and this rivet. This type of rivet is particularly suitable for more ductile thin sheet materials such as certain forms of rigid plastic, eg. glass reinforced materials.

The embodiment shown as rivet (80) is provided with a truncated conical mandrel head which will result in heat generation over a wider point area, thus softening the workpiece material over a larger area, and which will also continue to generate heat resultant from rotation of the rivet, resultant from subsequent engagement of the conical surface (81) engaging the side edges of the workpiece during the passage of this conical face of the mandrel head (22) therethrough. This type of rivet is particularly beneficial and suitable for use in thicker, less ductile, materials and also suitable for softer plastic materials.

The embodiment shown as rivet (90) corresponds substantially to that illustrated in Figure 1, but is further provided with a mandrel head having a substantially conical outer surface (91) with a central coaxial truncated portion (92) which is normally of cylindrical configuration. This truncated central portion (92) can be used to generate a local heat source or even a molten metal point and is particularly suitable for thicker less ductile sheet material. Again, the conical outer portion of the mandrel head (91) will continue to generate heat as it passes through and engages the workpiece about the periphery of the formed hole therethrough as rotation of the rivet is continued during such insertion.

Whilst these specific rivet designs are beneficial for use in this spin riveting method previously described, they are not essential to its operation and any form of mandrel

head is capable of generating heat through rotational engagement with the workpiece to provide a softening of such workpiece allowing the rivet to be driven therethrough at lower forces than would normally be associated and necessary to cause penetration.

An additional feature of the present invention can be a provision of an appropriate abrasive surface on the mandrel head or workpiece engaging end of the rivet body so as to increase the frictional resistance against rotation of the rivet during the setting operation to thereby significantly increase the heat generation. The abrasive surface further serves to abrade, erode and cause zones of weakness to be generated in the workpieces to again aid in insertion of the rivet therethrough. An example of such an abrasive surface could be the mounting of a relatively hard material such as carborundum or diamond dust onto the mandrel head or could simply be achieved by producing a work hardened mandrel head having appropriate hatching or other roughening of the external surface thereof. Since the mandrel and hence mandrel head are separate constructions to the rivet body, different materials can be used to achieve a different surface texture finish and hardness of the mandrel head to enhance the frictional resistance and thus heating effect during rotation, without impact on the ductility or strength of the rivet body necessary to effect appropriate collapse and setting.

Referring now to Figure 4, there is shown a schematic illustration of a static blind rivet insertion tool mounted in conjunction with a conventional "C" frame. Such "C" frame (60) is of conventional design having one arm (62) of such "C" frame supporting the rotatable rivet setting head (64) with the second, lower arm (66) of such "C" providing appropriate support for a plurality of workpieces (schematically illustrated at (68)). Since such static rivet insertion tools are employed on production lines, it is possible to connect these to conventional blind rivet feed mechanisms (70) which are standard within the art and need not be described in any great detail herein save to explain that they are capable of carrying a plurality of blind rivets (74) from a conventional vibrator bowl feeder along a conventional braceway via an escapement to such rivet feed mechanism so as to be easily accessible by the setting head (64) in a normal manner. The setting head (64) will be conventionally driven by pressurised air using a conventional main ram (76) for appropriate progressive insertion. The rotary setting head (64) will provide a combined means of effecting rotation of the blind rivet prior to the setting operation, with the main ram (76) providing an appropriate insertion force maintaining the rivet in frictional engagement with the workpiece (68) as previously

described. Once the rivet (74) has been inserted through the workpiece by combined application of rotary and progressive force thereon as previously described, the setting head is then restrained from further displacement while an effective blind rivet setting operation is carried out in a conventional manner.

A specific example of a blind rivet setting tool capable of effecting both rotation and subsequent setting of a blind rivet in the method previously described is clearly described in the Applicants earlier British Patent No. GB 1, 484, 259 which, by reference hereto, is considered to incorporate the technical description and drawings of the specific tool disclosed in that earlier publication into the current specification in its entirety and need not be described in detail herein. However, this example of a rotatable blind rivet setting tool is provided by way of example only and it will be appreciated that many variants are possible. Such combined rotary setting tool simply requires that conventional setting tool configuration of nosepiece and mandrel engaging jaws are rotatable prior to setting displacement of the mandrel engaging jaws during the setting operation. In addition, the manual or hand held setting tool illustrated in UK Patent No. GB 1, 484, 259 allows the operator to apply sufficient insertion force to maintain blind rivet engagement with the workpiece to create the frictional forces during rotation thereof, although it will be appreciated that where a stationery rivet setting structure used, such as that shown in Figure 4, appropriate hydraulic or electronic driven motor means may be sufficient to apply the insertion force to the setting tool.

In addition, it is to be recognised that the current invention is not limited to the specific design of blind rivet described herein. In particular, the current invention is equally applicable to any form of blind fastener and may specifically include other types of blind rivet such as closed end blind rivets, whereby the mandrel head does not extend beyond the longitudinal tail end face of the rivet body, but is retained therein. In such embodiment, the closed end face of the tail end of such blind rivet then provides a contact surface for frictional engagement with the workpiece during rotation whereby such frictional engagement will generate sufficient heat to allow the rivet to be driven through the softened workpiece. Here, the end face could be simply flat and perpendicular to the rivet axis or may be tapered or profiled similar to the mandrel head profiles shown in Figure 3. Where the mandrel head is retained within the rivet body, then frictional engagement between the mandrel and the rivet body will often be sufficient to transmit the rotational force through the mandrel stem to the rivet body during rotation against the workpiece. However, such engagement between the

mandrel stem and the rivet body can be enhanced by providing the internal cross sectional profile of the rivet body and the external cross sectional profile of the mandrel stem with a geometric design so as to provide positive rather than frictional engagement between the mandrel stem and the rivet body during rotation. For example, the mandrel stem may be squared to be received within a square aperture of corresponding shape and size of the rivet body. Similarly, the cross sectional profile of the mandrel stem may be geometrically profiled so as to be triangular, square or some other form of geometric shape and to provide a better positive engagement between the gripping jaws of the rivet setting tool and the mandrel stem such gripping tool is employed to apply a rotational force to effect rotation of the blind rivet for use in the method previously described.